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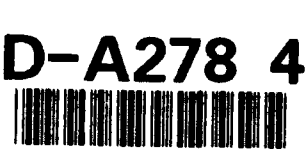

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It has been shown that the ultimate limits for some classes of multi-user communications systems can be computed by single linear programs. This theory can be applied to ordinary telephone networks and to TDMA communications networks.

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Final Technical Report, October 1, 1990–September 30, 1993

RELIABLE COMMUNICATION IN THE PRESENCE OF SEVERE NOISE OR JAMMING

(AFOSR Grant 91-0037)

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The long-term goal of this project has been to obtain a basic mathematical understanding of the problems associated with communication in the presence of severe noise, e.g., fading, jamming or interference from other (friendly) signals. Our basic approach has always been to apply the techniques and insights of *information theory* to these problems. In the period covered by this report, we continued, and greatly extended, our study of models for *multi-user* communication systems, i.e., systems in which many simultaneous two-way conversations must share a common band of frequencies. We have shown (refs. [4],[5],[6],[7],[9]) that the ultimate limits for such systems (measured by the number of conversations per unit of available bandwidth) can, in some cases, be computed by a fairly simple linear program. Later, we extended this work (ref. [16]) to show that it applies to the more general class of *blocking service networks*, i.e, networks which provide many kinds of service to many customers simultaneously. Besides "cellular" communication networks, we have already shown that our new theory also applied to ordinary telephone networks, and to stochastic "bin packing" TDMA communication networks. Most recently, we studied the performance of a class of practical bandwidth allocation algorithms, the "distributed dynamic" algorithms, and showed (ref. [21]) that in many cases they are nearly optimal.

We are are continuing, under AFSOR grant no. F49620-94-1-0005, to explore this extremely fertile research area. In particular, we believe we are close to a proof that the distributed dynamic algorithms referred to above are asymptotically optimal in a very strong sense, viz., for any value of the (normalized) offered traffic, as the number of channels becomes large, the carried traffic for these algorithms equals or exceed that of any other algorithm.

Also, our research included a study of the comparative performances of various modulation schemes in cellular radio systems (refs. [13],[14],[17],[18,[20]). In this work, we demonstrated the clear superiority of spread-spectrum (e.g. FH or CDMA) over non-spread (e.g. FDMA or TDMA) systems. This work is also continuing, and we hope, having an impact in the current lively debate among cellular system designers about which modulation scheme to use in the next generation of commercial and military cellular communication systems.

AFOSR-sponsored publications in the reporting period.
(entries marked "•" are in refereed, archival journals.

1. •"Performance of Binary Block Codes at Low Signal-to-Noise Ratios" (with C.-c. Chao, Eugene Rodemich, and Laif Swanson), *IEEE Trans. Inform. Theory* vol. IT-38 (1992) pp. 1677–1687.

2. "Some Properties of Memoryless Multiterminal Interference Channels," (with M. Mandell), Proc. 1991 International Symposium on Information Theory, p. 212.

3. "Dynamic Channel Assignment in Cellular Radio" (with Kumar Sivarajan and John Ketchum), Proc. 1990 IEEE Vehicular Technology Conference, pp. 631–637.

4. "Performance Limits for FDMA Cellular Telephone Systems" (with Kumar Sivarajan), Proc. 1990 Allerton Conference on Communication, Control, and Computing, pp. 869–880.

5. "Performance Limits for Cellular Telephone Systems Defined by Hypergraphs," (with. Kumar Sivarajan), Proc. Third IEE Conf. Telecommunications (Edinburgh, March 1991), pp. 360–365

6. "Performance Limits for Cellular Multiuser Communications Systems," (with K. Sivarajan), proc. Proc. 1991 International Symposium on Information Theory, p. 212.

7. "Asymptotic Performance of Fixed and Dynamic Channel Assignments in Cellular Radio," (with. Kumar Sivarajan), Proc. 1991 International Symposium on Information Theory, p. 154.

8. "Some Properties of Memoryless Multiterminal Interference Channels," (with M. Mandel), Proc. 1991 International Symposium on Information Theory, p. 212.

9. •"Performance Limits for Channelized Cellular Telephone Systems", (with Kumar Sivarajan) accepted in Oct. 1992 for publication in *IEEE Trans. Inform. Theory*.

10. "The Extended Invariant Factor Algorithm with Application to the Forney Analysis of Convolutional Codes" (with Ivan Onyszchuk), Proc. *1993 Int. Symp. Inform. Theory*, p. 142.

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13. "Maximal Codeword Lengths in Huffman codes," (with Y. S. Abu-Mostafa), to appear in the proceedings of "GolombFest 60" (a symposium held to celebrate the 60th birthday of Professor Solomon W. Golomb, May 29–31, 1992.)

14. "A Comparison of CDMA and Frequency Hopping in a Cellular Environment," (with M. Mandell), Proc. First International Conference on Universal Personal Communications (UPC '92). Dallas: Sept. 29–Oct. 2, 1992, pp. 07.01.1–07.01.5

15. "Heavy Traffic Performance of a Class of Channel Assignment Algorithms," (with K. Sivarajan), Proc. Third International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC '92). Boston: October 19–21, 1992, pp. 550–555. (Also published as IBM Research Report RC 18212 (79916).)

16. "Maximizing Marginal Revenue In Generalized Blocking Service Networks," (with K. Sivarajan), Proc. 1992 Allerton Conference on Communication, Control, and Computing, pp. 455–464.

17. "A Comparison of CDMA and Frequency Hopping in a Cellular Environment," (with M. Mandell). Proc. *1993 Int. Symp. Inform. Theory*, p. 252.

18. *A Comparison of CDMA and Frequency Hopping in a Cellular Environment*, by Michael I. Mandell. Caltech Ph.D. thesis. November 25, 1992.

19. •"Phased Burst Error Correcting Array Codes," (with R. Goodman and M. Sayano), *IEEE Trans. Inform. Theory* IT-39 (March 1993), pp. 684–693.

20. "Comparison of the Capacities of CDMA, FH, and FDMA Cellular Systems," (with M. Izumi and M. Mandell), proc. *Wireless 93* (The Fifth Annual International Conference on Wireless Communications), Calgary Canada, July 1993, pp. .

21. "Why Channel Assignment Algorithms are Asymptotically Smart," with E. R. Rodemich. 1993 Allerton Conference on Communication, Control, and Computing, September 1993, *in press*